TITLE

A biomechanical investigation into the rugby lineout lift and comparison to the barbell push press and strongman log press

AUTHOR

Driver, Oliver

DATE DEPOSITED

20 October 2017

A biomechanical investigation into the rugby lineout lift and comparison to the barbell push press and strongman log press

Oliver Driver

This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University

First supervisor

Phil Price

Second supervisor

Emily Cushion

Table of contents

List of figures

List of tables

ABSTRACT

The aim of this study was to determine the mechanical similarity between rugby lineout lift (RLL) compared to two training movement demonstrating dynamic correspondence; the barbell push press (BBPP) and the strongman log press (SMLP). 8 rugby players (age 29 ± 6.8 years, height 1.84 ± 0.05 meters, weight 107.4 ± 16.2kg) performed 3 RLL lifting a 105kg player from the posterior position. Each subject also performed 3 BBPP and 3 SMLP both loaded at 52kg. Joint angles and peak force were measured throughout the lifts. Differences of peak and average force were analysed. Peak flexion angles were calculated at the ankle, knee and hip. Time taken to reach peak force were calculated and analysed across lifting conditions. Joint angles demonstrated significant differences ($p \leq 0.05$) at ankle, knee and hip through full range of motion between RLL and both BBPP and SMLP. SMLP demonstrated significant difference ($p \leq 0.05$) in time to peak force compared to RLL. BBPP demonstrated significant difference ($p \leq 0.05$) in peak force compared to the RLL.

The RLL demonstrates increased angles of hip flexion and extension resulting in a smaller hip angle and angled torso position. Both the BBPP and SMLP demonstrate increased angles of knee flexion and extension with minimal hip involvement, a higher hip angle and more upright torso position. The current results suggest that there is a low correspondence of mechanical similarity between the RLL and both the BBPP and SMLP. Therefore, BBPP and SMLP should be programed for use during offseason periods to prepare the athlete for the competitive season and more specific training for the RLL.

KEY WORDS: Kinetics, Kinematics, Correspondence, Transfer, Specificity

INTRODUCTION

The rugby lineout (RL) is a resetting of play following the ball going out of bounds across the side-line. It occurs frequently during matches, between 18 – 38 times (15) and can lead to increased scoring opportunities. For example, during the 2015 Rugby World Cup 51% of tries originated from lineouts compared to 15% from scrums (15). It is an important component in the game of rugby and increases opportunities for securing victory. When the ball is knocked out by the team in possession during open play the opposition will get to control the RL. Both forward players of each team line up parallel to each other opposite the side-line. The retaining team's hooker will throw the ball directly down the middle of the lines of players. The retaining team's second row then attempts to catch the ball as it returns into play. As the designated player jumps to catch the ball they are aided by the props and flankers who grasp the second row's thighs and use an explosive extension of their lower limbs to lift them into a higher position for the catch. This results in most RL throws being caught approximately 3–3.5 meters above the ground however, the height varies in relation to the throw (26, 27, 30), as does the height of the jumper and the stature and ability of lifters. The current lack of literature limits the selection of suitable training application as there is no existing data. Training activities that elicit triple extension of the lower limb demonstrate kinetic and kinematic correspondence to sporting movements (1, 6, 15, 21, 22) and improved performance through direct transfer (6). Movements such as these may increase performance of the RLL.

To the author's knowledge all existing data on RL is limited to biomechanical investigations into throwing (26, 27, 30). At present, there is no kinematic or kinetic data on the lifting component of players during a RL. Consequently, any research data used to inform coaching practices of the rugby lineout lift (RLL) will originate from more general investigations from sources not specific to the RL, such as jumping (21, 22) and weightlifting (6, 10, 15, 23, 29) which have been thoroughly investigated with large bodies of research behind them. However, recent research (7, 8) investigating the mechanical similarity of weightlifting and vertical jumping demonstrates a more nuanced relationship between biomechanics of the lower limb when performing resistance exercises compared to vertical jumping that is similar to sporting movements. These studies (7, 8) demonstrate that although similarities exist between corresponding movements subtle differences also occur. Adding biomechanical data to existing research on the RL may help identify sport specific motor qualities such as triple extension of the lower limb and movement control strategies during the RL, thereby leading to improved performance during RL.

Cleather et al. (7), state that joint moments of the lower limb can vary during the countermovement jump depending upon on an individual's movement strategy employed for jumping. However, joint moments during the push jerk remained consistent. Individual variation was cited as the reason for individual differences in the countermovement jump movement strategy while the position of the loaded barbell during the push jerk limited individual movement strategies and resulted in a more consistent knee dominant movement strategy across subjects. Cushion et al. (8) demonstrated that the push jerk and jump squat have significant correlations to countermovement jump at knee moment and impulse and hip moment and impulse at lower percentages of 1 repetition maximum (1RM%); jump squat at 25%1RM and push jerk at 30 and 50%1RM. A review paper authored by Beardsley and Contreras (2) asserts that proportional involvement of the hip increases and knee decreases with increasing loads during squat, lunge and deadlift exercises. Also, the ratio of hip-to-knee extensor moments increases with increasing jump height and running speeds (20, 27) thus adding support to the notion that movement control strategies and resulting outcomes are affected by position and load. However, data from weightlifting movements, specifically the jerk was omitted from the review (2). Evidence (7, 8, 39) suggests that anteriorly positioned load will affect limb kinematics by limiting hip flexion/extension and increasing knee dominance.

Research (7, 8) has demonstrated that during execution of jerk variants the load is situated anteriorly restricting contribution of the hip and increasing knee involvement. This control strategy results in maintaining torso position so as not to tip and lose the bar forward. Winwood et al. (39) demonstrated that this position is emphasized when using larger diameter training implements when moving load overhead. Research (39) demonstrates statistically significant differences between a barbell weightlifting clean and jerk (WCJ) and a strongman log clean and jerk (SMLCJ) in trunk 90.7 ± 6.0° compared to 105.8 ± 2.4° ($p<0.002$), hip 158 ± 14.8° compared to 1823.3 ± 5.3° ($p<0.005$) and knee 124.5 ± 13.4° compared to 138.8 ± 11.1° ($p<0.033$) angles. The resulting kinematic differences illustrate the movement strategy of the SMLCJ that maintains a higher hip angle and more upright torso when compared to the WCJ. These findings suggest that it is the larger diameter of the strongman log that causes the kinematic and kinetic differences. When considering the movement of larger, awkward and more unstable objects questions arise as to what effects it would have upon movement control strategies; specifically, torso, hip and knee positions. For example, with lack of existing information for the RLL it is unclear how lifting during the RL affects torso, hip and knee positions and control strategies.

The WCJ exhibited significantly greater peak vertical velocity in the jerk 1.82 ± 0.09 m.s-1 compared to SMLCJ 1.60 ± 0.10 m.s-1 ($p<0.002$) along with significantly greater ($p<0.009$)

peak power of 5629 ± 1565W compared to SMLCJ 3699 ± 618W and significantly greater ($p<0.041$) mean power 2960 ± 802W compared to SMCJ 1922 ± 591W. These differences were attributed to the smaller diameter of the barbell compared to the log and its closer position to the subjects' body allowing for more advantageous power application. Subjects were national and regional strongman competitors weighing 112.9 ± 28.9kg that use long periods of resistance training time (90.8 ± 30.4 minutes per training session, 4.2 ± 1.2 resistance session per week) to prepare for specific strongman competition. While this information is useful, kinetic and kinematic outcomes may differ when performed by field based sport athletes. They use resistance training to increase sport performance rather than training a specific resistance exercise for performance of that lift in a competitive arena. Field based sport athletes spend less time training in the gym and have less experience using strongman-training implements than strongman competitors (3, 36, 39, 40, 41). The lack of exposure may cause a reduction of practice effect and control strategies. This then, may affect the kinematic and kinetic similarities of the WCJ and SMLCJ and suitability for implementation in training athletes. Determining detailed kinematic and kinetic data may provide useful information about the SMLCJ and its implementation into field based sport athletes training programs, it's dynamic correspondence and its suitability within different phases of athletes' programs.

Strongman type resistance exercises using odd and unusual shaped implements are increasingly gaining credence in the strength and conditioning community. Recent research has been carried out on the biomechanics of strongman equipment (17, 18, 30, 38, 39, 41, 42), metabolic demands (4), hormonal responses (12), muscle electromyographic (EMG) data (24) and injury occurrence (38). Literature on the SMLP is growing and its use by strength and conditioning coaches as an effective training stimuli for development of strength, power and stability is increasing (42). Its use has been stated to increase athlete adherence to training due to its novel nature (37) and used as a tool for the enhancement of different physical qualities (14). It has also been stated that the neutral hand placement on a strongman log is more specific to sporting movements, such as the RLL than a pronated grip on a barbell (45). The use of strongman type implements has been demonstrated to challenge balance and control strategies (24, 36, 37, 39, 41, 42) making it worthy of investigation and comparison to the RLL. During performance of the RLL the player lifting must exert force upon a player jumping for the catch. The load is therefore asymmetrical (another human) and situated anteriorly, moving chaotically and possibly away from the lifter. These factors will have an impact upon the biomechanics of the lift but, it is unclear as to how they affect it compared to more constant and controlled stimuli such as the barbell push press (BBPP) or strongman log press (SMLP). The BBPP has been demonstrated as an effective intervention to train the lower body with a power stimulus and the upper body with a pressing stimulus (19). However, examination of the biomechanics of each lift by an appropriate rugby cohort remain to be established and compared to the RLL.

The gap in existing knowledge of the biomechanics of the RL leaves room to investigate how contributions of the lower limb during performance of the RLL correspond to traditional (barbell) and non-traditional (strongman) type training movements that like the RLL involve both countermovement, lower limb triple extension and upper body overhead pressing. Therefore, the BBPP and SMLP have been selected for testing and comparison against the RLL. A question of how different sized diameters and location of anteriorly positioned load effects torso, hip knee and ankle angles exists. An investigation is warranted into the use of these implements, how they influence joint angles and the mechanical similarity of each lift. The correspondence of the BBPP and SMLP to the RLL will be considered as the resulting data will make clear if it's appropriate to use either of them as a specific training stimuli or, one more general to the RLL. For a more conclusive dataset and comparison, kinetics will also be measured for a more complete picture and comparison. The external kinetic data can be displayed by measurements of ground reaction force (GRF) and provide some detail of biomechanical similarity.

The aim of this study is to ascertain the kinematics and kinetics of a RL lifter when lifting a teammate as if catching a ball from a RL throw. The kinetics and kinematics of two common training movements, the BBPP and SMLP will also be measured and compared to the RLL for biomechanical similarity. With consideration of preceding research, (8, 39) it is also hypothesized that the RLL will share a higher degree of biomechanical similarity with the SMLP compared to the BBPP. That is, the RLL features a more anteriorly positioned load that, when lifted, will move anteriorly, similar to the SMLP. The execution of the RLL will necessitate a higher hip angle, more upright torso position and increased reliance upon the knee joint for peak force development. It is also hypothesized that during the RLL peak force will be lower than SMLP due to the anterior position, unstable nature and awkward shape of the load lifted.

METHODS

Experimental approach to the problem

A crossover design was used to test the hypothesis to yield an efficient comparison of lifting conditions. Subjects performed 3 attempts of the RLL followed by 3 attempts of the BBPP and 3 attempts of the SMLP in this exact order. Kinetic and kinematic data were recorded via portable force plates and a high-speed video recorder. Kinematic and kinetic data was then compared between each condition to test the hypothesis.

Subjects

Subjects were provided with a consent form which was signed prior to the study commencing to obtain informed consent. Subjects who currently had an injury such as joint or, muscle pain were not be eligible to participate in case the study were to aggravate any existing conditions. Anthropometric measurements were completed individually with body mass being obtained using an electronic scale (Tanita BC 418, Japan) accurate to within 0.1kg. Body height was measured using a wall mounted Stadiometer (SECA, Germany) Eight healthy male subjects (Table 1.) were recruited from Lincoln Rugby Union Football Club, a semi-professional rugby team.

Table 1. Subject information

Subjects (n=8)	
Age (years)	29 ± 6.8
Height (meters)	1.84 ± 0.05
Weight (Kg)	107 ± 16.2

Subjects consisted of eight forward positions, as these are the positions during a rugby game that will be used during the RLL. Of these eight subjects only six were tested, as one subject was required to maintain a jumping/receiving position and one subject remained in the anterior lifting position as in game conditions, all were familiar with the RLL and performed it on a regular basis in training and in games. All subjects were familiar with the BBPP and SMLP and had used both loading apparatus previously in their respective training programs. Subjects were verbally informed about the research project prior to testing and each was supplied with a written participant information form. Testing commenced at Riseholme Park, Lincoln rugby club's training facility. This study was approved by the St Mary's University Research Ethics Committee.

Procedure

Subjects followed a standardized warm up protocol (Table 2.) and were asked to wear comfortable training clothing. They were permitted to continue regular training activities outside of the testing but asked to refrain from any intense exercise 24 hours prior to test day. Each participant performed attempts of the RLL followed by BBPP and SMLP, this was for logistical reasons as testing was during the competitive season it needed to be completed in a timely manner so that the subject could rejoin their training session. The RLL was completed first thereby allowing both the jumper and anteriorly positioned lifter time to recover between participant attempts of the RLL such that they can rest during attempts of BBPP and SMLP. The barbell and strongman log were then used in this order so that minimal time was spent changing the bars in-between testing conditions.

Table 2. Standardized warm up protocol prior to testing

Order	Movement	Repetitions	Sets	Load
A1.	Squat	10	3	Bodyweight
A2.	Press Ups	10	3	Bodyweight
A3.	Lunge	10	3	Bodyweight
B1.	Barbell Overhead Press	10	3	20Kg
B2.	Barbell Back Squat	10	3	20Kg

Rugby Lineout Lift

Subjects performed 3 repetitions of the RLL. It began with test subjects (TS) positioned to the posterior of a 105kg subject acting as the jumper. An assistant additional anterior lifter (AAAL) was another forward and had a mass of 115kg. TS were instructed to perform the RLL as in game conditions but without a hooker throwing a ball. That is, both the AAAL and TS lift the jumper as he performed a countermovement jump. Subjects started in a semi-upright position, as they felt was necessary, the TS placed their hands upon the jumper below the hip (greater trochanter) while the AAAL placed both hands upon the jumper slightly above the knee (lateral ridge of tibial plateau). Once the jumper initiated a countermovement the TS and AAAL increased force and aided the jumper in reaching the highest position possible upon the jump. Previous research (13) has established that subjects with a history of training demonstrate a high degree of reliability between repetitions when self-selecting rest periods. Subjects were well trained and experienced and were trusted in self-selecting their own rest periods; this also ensured they could perform maximally and were recovered between each attempt.

Barbell Push Press

The BBPP began with subjects in an upright position with the barbell held with a pronated grip across the clavicles in a front squat position. Subjects then performed a countermovement as deemed necessary before extending the lower limbs and pressing the barbell overhead, extending the arms and locking out the elbows. Three repetitions were performed with self-selective rest period between attempts. The total weight of the barbell was half the mass of the jumping subject during testing. As only the TS was lifting the barbell it was set at 52kg.

Strongman Log Press

The SMLP began with subjects in an upright position with the strongman log held in a neutral grip at the clavicles. However, due to the neutral handle position and the large circumference, the grip on the log was further forward and away from the subject's centre of mass. Subjects then performed a countermovement as deemed necessary before extending the lower limbs and pressing the barbell overhead, extending the arms and locking out the elbows. Three repetitions were performed with self-selective rest period between attempts. The total weight of the barbell was half the mass of the rugby forward jumping subject during testing. As only the TS was lifting the strongman log it was set at 52kg.

Instrumentation

A 20kg Olympic weightlifting barbell (Again Faster, Nottingham, UK) was used for BBPP along with weightlifting bumper plates (Exertrain, Savage Strength, Wiltshire, UK), for the SMLP a 30kg metal strongman log (Savage Strength, Wiltshire, UK) was used along with the weightlifting bumper plates. Markers were placed on bony landmarks of anatomical structures on the shoulder (acromioclavicular joint), hip (greater trochanter), knee (lateral ridge of tibial plateau), ankle (apex of the lateral malleolus), and the head of second metatarsal (41, 42). Kinematic data was collected using a high-speed video camera (Panasonic V210 HD Camcorder, Panasonic, Berkshire, UK) sampling at 250Hz. The camera was positioned perpendicular to the right-hand side of the subjects (sagittal plane view) 2 meters away from the centre of the force platforms. The image was calibrated using 2 poles of known height (1.60m) placed 0.60m apart in the centre of the field of view. The centre of the lens was 1m high. For kinematic data, a rigid 2D linked four segment model/ joint angles (trunk, hip, knee and ankle) was used (Figure 1.) and each marker was transformed into co-ordinate data using appropriate software (Kinovea, 0.8.15, France). Joint angles were measured at θh, θk and θa for each condition at each of the following movement phases; i) top/start of each movement, (start of countermovement) ii) bottom of the dip and drive (bottom of countermovement), iii) lift completion when joints reached peak extension. The distinct phases were used to measure what, if any, differences occur to lower limb joint angles from beginning the movement to lift completion holding the load overhead with shoulders flexed and elbows extended. Kinetic data was collected using two portable force plates (Pasport Force Platform PS-2141, 370 mm x 370 mm; Pasco, Roseville, CA, USA) sampling at 250Hz, arranged within a surrounding platform structure. Peak values were identified for each subject's 3 attempts in each lifting condition in Microsoft Excel and the mean value was used for analysis.

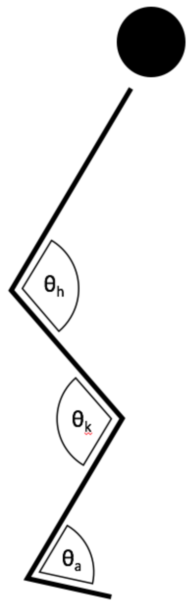

Figure 1. Joint angles derived from the linked segment model of the body across all loading conditions during the RLL, BBPP and SMLP θh = hip, θk = knee, θa = ankle

Data Analysis

Kinetics

Means and SD were calculated using SPSS. Force data for BBPP, SMLP and RLL displacements were normalized for time using ensemble averaging in Microsoft Excel. Analysis began from the start of the countermovement in each lifting condition and concluded at the highest point following the countermovement. The highest point was recorded as peak power. Mean power was calculated by averaging power from the start of the countermovement and over the propulsive phase. Time to peak force was also measured from the initiation of countermovement to lowest force and from that point to peak force.

Kinematics

Joint angles were measured (figure 1.) at θh, θk, and θa across all loading conditions. The first joint measurement was taken as subjects stood erect at top/start position (TS) before initiating the countermovement. Second joint measurements were taken following subject initiation of the countermovement as they reached the lowest position - the bottom of dip drive (BDD). The third angle measurements were taken as subjects reached peak extension at LC when standing erect with lower limb extended, holding the load overhead with shoulder flexed and elbow extended (Figure 2.).

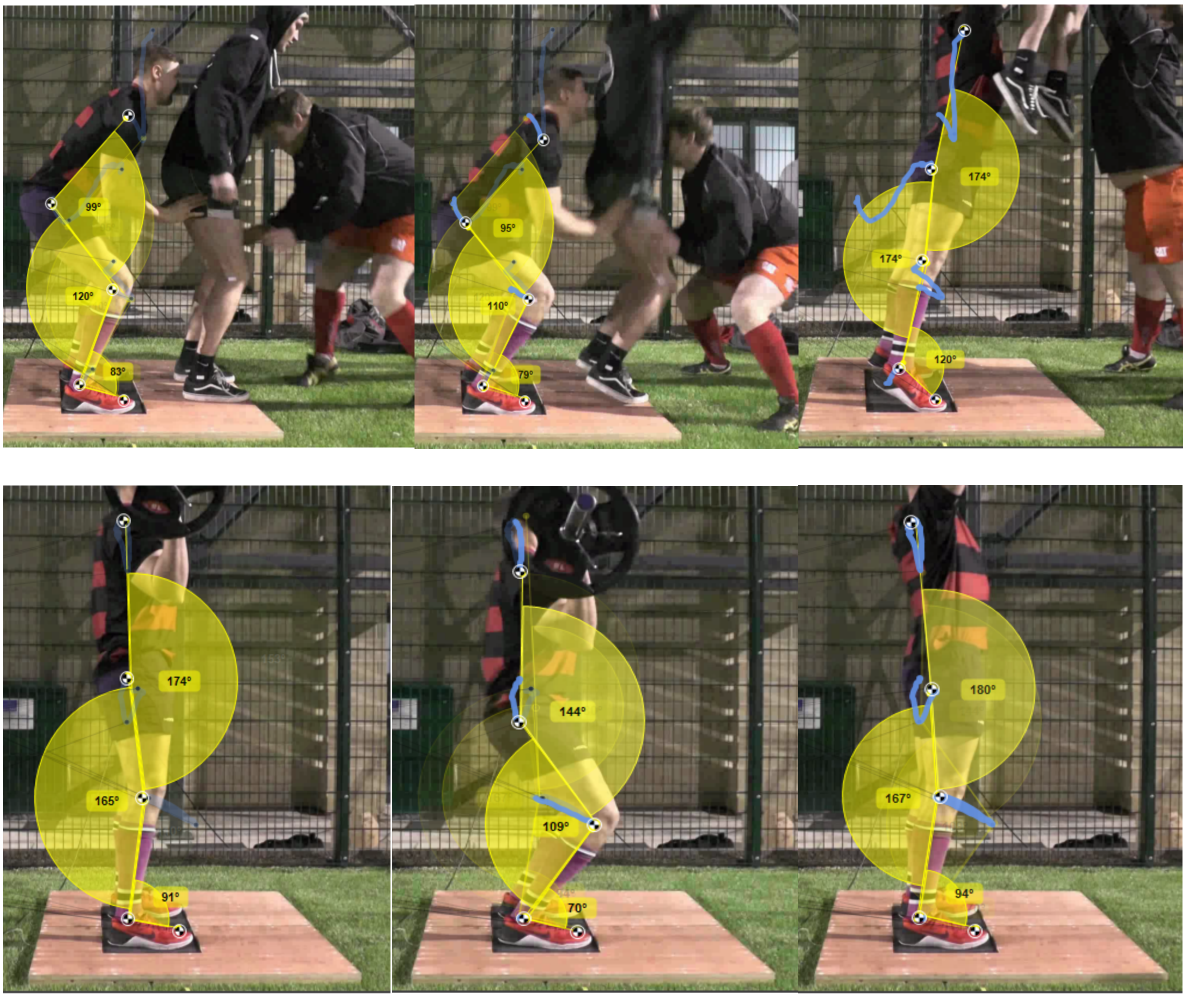

Figure 2. A pictorial demonstration of the 3 angles measured during lifts across all loads; RLL, BBP and SMLP (not seen). Angles measured at i) Top Start (TS), ii) Bottom of Dip Drive (BDD), and iii) Lift Completion (LC)

Statistical Analysis

A one way repeated measures analysis of variance (ANOVA) was used to compare the dependent variables between experimental conditions. Greenhouse-Geisser corrections were used when Mauchly's Test of Sphericity was violated. Bonferroni adjusted t-tests were used for post hoc testing when ANOVA produced significant results. A Pearson product moment correlation was calculated to determine kinematic and kinetic variables that correlated most highly with those matching the RL. Significance level was set at $p \leq 0.05$ for all data. Interpreting correlations, the following guidelines are established: trivial, $r<0.01$; small, $r=0.10 – 0.30$; moderate, $r=0.30-0.50$; large, $r=0.50-0.70$; very large, $r=0.70-0.90$; and nearly perfect, $r=0.90+$. Data was analyzed using Windows Microsoft Excel 2007 (Micosoft Corp; Redmond, WA, USA) and IBM SPSS Statistics (Version 22; IBM Corp, Chicago, IL, USA).

RESULTS

Kinematics

TS Position

During the TS the knee angle of BBPP (154.0 ± 12.8°) demonstrates a significant difference ($t(17) = 5.89$, $p < 0.01$) and SMLP (153.5 ± 7.4°) ($t(17) = 5.127$, $p < 0.01$) compared to RLL (124.2 ± 23.3°). A significant correlation exists between BBPP and SMLP knee position ($r = 0.658$, $t(17) = 5.67$, $p < 0.01$). The hip angle of BBPP (175.0 ± 6.4°) demonstrates a significant difference ($t(17) = 7.99$, $p < 0.01$) and SMLP (177.2 ± 3.2°) ($t(17) = 7.89$, $p < 0.01$) compared to RLL (110.5 ± 30.7°).

BDD Position

The ankle angle demonstrates a significant difference ($t(17) = -2.15$, $p < 0.05$) between RLL (76.8 ± 13°) and BBPP (73.5 ± 7.9°). The knee angle of BBPP (114.5 ± 13.9°) demonstrates a significant difference ($t(17) = 6.73$, $p < 0.01$) and SMLP (115.9 ± 12.2 °) ($t(17) = 8.46$, $p < 0.01$) compared to RLL (80.4 ± 15.9°). The BBPP and SMLP demonstrate significant correlation ($r = 0.827$, $t(17) = -15.63$, $p < 0.01$) at the knee angle. The hip angle of BBPP (158.9 ± 15.4°) demonstrates a significant difference ($t(17) = 13.60$, $p < 0.01$) and SMLP (163.1 ± 4.2°) ($t(17) = 23.65$, $p < 0.01$) compared to RLL (76.8 ± 13.0°).

LC Position

The ankle angle of SMLP (94.0 ± 7.6°) demonstrates significant difference ($t(17) = -2.29$, $p < 0.01$) compared to RLL (101.5 ± 11.4°). The knee angle of BBPP indicates significant correlation ($r=0.556$, $t(17) = -5.48$, $p < 0.05$) with the RLL. The knee angle of SMLP also indicates significant correlation ($r = 0.665$, $t(17) = -7.83$, $p < 0.01$) with the RLL. The hip angle of BBPP (180.0 ± 0°) demonstrates a significant difference ($t(17) = 2.85$, $p < 0.05$) and SMLP (179.0 ± 0.2°) ($t(17) = 2.79$, $p < 0.05$) compared to RLL (175.5 ± 6.0°). Kinematic data can be observed in Table 3.

Time to Peak Force

Time to peak force can be observed in Table 4. A significant difference ($t(17) = 4.02$, $p < 0.05$) was seen between RLL (0.19 ± 0.46s) and SMLP (0.30 ± 0.8s) during the decent from TS to BDD.

Table 3. Mean ± SD normalized peak hip, knee and ankle joints across loading conditions during the propulsive phase of the movements

		RLL	BBPP	SMLP
Top start (TS)	Hip (°)	110.5 ± 30.7	175.0 ± 6.4 **	177.2 ± 3.2**
	Knee (°)	124.2 ± 23.3	154.0 ± 12.8 **	153.5 ± 7.4 **
	Ankle (°)	90.6 ± 7.5	92.2 ± 6.9	89.6 ± 5.3
Bottom of dip and drive (BDD)	Hip (°)	76.8 ± 13.0	158.9 ± 15.4 **	163.1 ± 4.2**
	Knee (°)	80.4 ± 15.9	114.5 ± 13.9**	115.9 ± 12.2 **
	Ankle (°)	76.8 ± 13	73.5 ± 7.9 *	75.6 ± 4.7
Lift Completion (LC)	Hip (°)	175.5 ± 6.0	180.0 ± 0 *	179.0 ± 0.2 *
	Knee (°)	169.5 ± 8.1	160.0 ± 6.0	156.6 ± 7.9
	Ankle (°)	101.5 ± 11.4	97.8 ± 11.9	94.0 ± 7.6 *

RLL = rugby lineout lift; BBP = barbell press; SML = strongman log lift
* Significant difference between BBPP/SMLP and RLL $p \leq 0.05$
** Significant difference between BBPP/SMLP and RLL $p \leq 0.01$

Table 4. Mean ± SD normalized time for movement of start of decent and to peak force across loading conditions

	RLL	BBPP	SMLP
Start of decent (s)	0.19 ± 0.46	0.27 ± 0.94	0.30 ± 0.8 *
To peak force (s)	0.30 ± 1.4	0.35 ± 0.11	0.36 ± 0.08

RLL = rugby lineout lift; BBPP = barbell press; SMLP = strongman log lift
* Significant difference between BBPP/SMLP and RLL at $p \leq 0.05$

Kinetics

Peak force

There was a significant difference ($t(17) = 2.82$, $p < 0.05$) between RLL (154.2 ± 46.9N) and BBPP (209.5 ± 35.2N). A very high correlation ($r = 0.928$, $t(17) = 1.79$, $p < 0.05$) was noted between BBPP (209.5 ± 35.2) and SMLP (194.7 ± 47.9N). Results can be seen in Figure. 3.

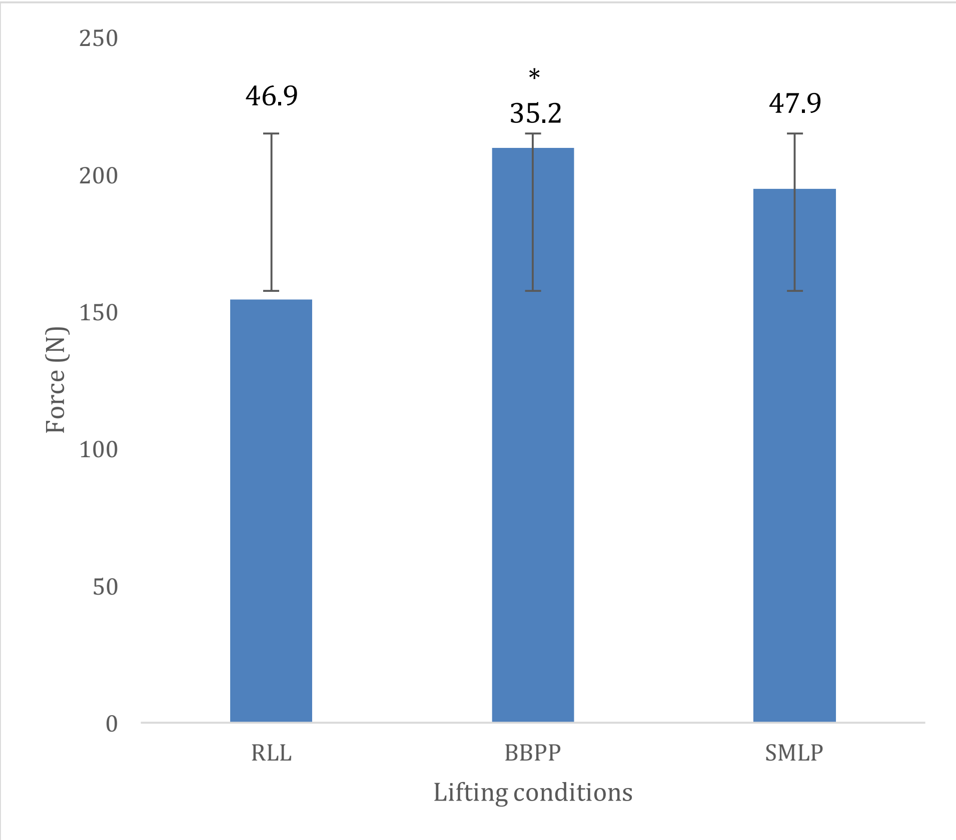

Figure 3. Mean ± SD peak force across lifting conditions.

∗ Significant difference ($p \leq 0.05$) between BBPP and RLL

Mean Peak Force

There was a significant difference ($t(17) = -3.72$, $p < 0.05$) demonstrated between RLL (100.1 ± 19.6N) and BBPP (129.5 ± 17.5N). Results can be seen in Figure. 4. No significant differences were seen elsewhere.

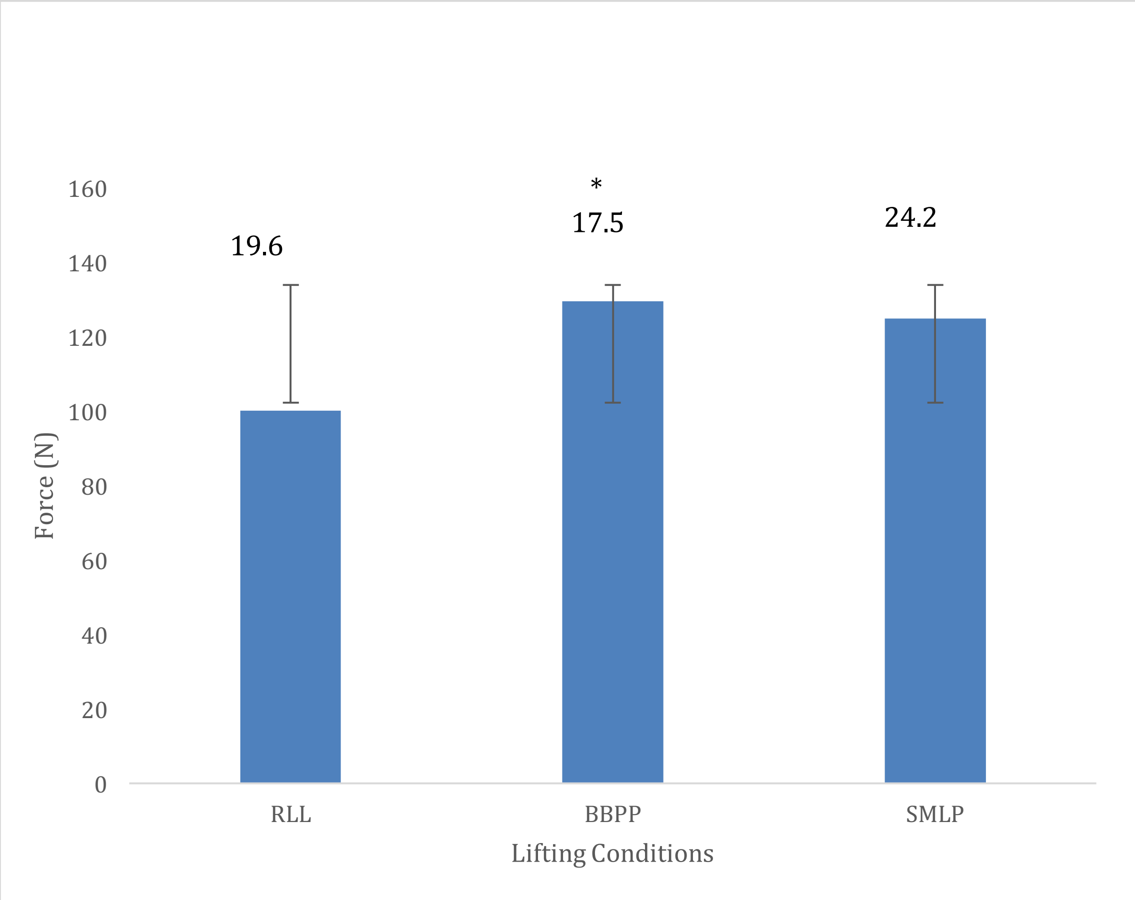

Figure 4. Mean ± SD average force across lifting conditions

∗ Significant difference ($p \leq 0.05$) between BBPP and RLL

DISCUSSION

The purpose of the current study was to examine the mechanical similarity of the BBPP and SMLP compared to the RLL. This study showed that there was significant difference ($p \leq 0.05$) between angles of ankle, hip and knee of RLL compared to BBPP and SMLP during the start position, countermovement and finishing position. There was also significant difference ($p < 0.05$) between peak and mean peak force between the BBPP and RLL. The BBPP and SMLP displayed significant correlations (r=0.658 – 0.827) at the knee angle during all 3 positions. As a result of this investigation, the null hypothesis was not rejected and it is accepted that there is little biomechanical similarity between both BBPP and SMLP compared to the RLL. In contrast, the BBPP and SMLP do show kinematic correlations and a very significant, almost perfect correlation in peak force ($r = 0.928$, $p \leq 0.01$). This was somewhat surprising as the RLL used a much larger range of motion at the hip than anticipated. In contrast the BBPP and SMLP demonstrated minimal hip flexion and extension with a reliance upon knee flexion and extension to generate sufficient power to move the load overhead. There were key differences in movement strategies between all 3 lifting conditions.

Subjects performing the RLL started in a position as they would when performing the movement in a game. It is a crouched, more athletic position then BBPP or, SMLP, with increased knee and hip flexion. As movement is initiated from TS all subjects across the 3 lifting conditions perform a countermovement flexing the joints of the lower limb and transition into the BDD position. This is where all 3 lifts reach the peak knee angle. The RLL demonstrates increased hip (33.7°) and knee (43°) flexion compared to hip flexion of BBPP (16.1°) and SMLP (14.1°) and knee flexion of BBPP (39°) and SMLP (37°). However, at the ankle during this phase RLL has the smallest range of motion (13.8°) compared to BBPP

(18.7°) and SMLP (14°). This movement strategy demonstrates significant difference between BBPP and SMLP compared to RLL. During the RLL the hips descend further than BBPP and SMLP causing a much more acute angle at the knee. The ankle has significantly less RoM than BBPP or SMLP causing a more vertical shin angle. This strategy demonstrates a high degree of hip flexion. It contrasts with both BBPP and SMLP that use less movement at the hip and knee and generate less peak angle. Both BBPP and SMLP utilize increased RoM at the ankle.

The increased range of movement of RLL compared to BBPP and SMLP during the countermovement can be attributed to the position of the load. The RLL requires lifting of another player that is situated in a further anterior position than BBPP and SMLP. The loading position requires that the lifter initiates movement with increased range of motion into a more flexed position than either BBPP or SMLP ready to accept the load as the jumper moves vertically in front of the lifter. During the RLL as the subject extends the lower limbs and accepts the load of the jumper, the direction of force is more anterior for the subject. This necessitates the subject to lift vertically and horizontally as they push the jumper both overhead. The direction of force necessitates the subject to have an angled torso and smaller hip angle In contrast to the RLL, both the BBPP and SMLP have the load situated closer to the subjects' center of mass resting across the clavicles and anterior deltoids in a front squat position. This necessitates subjects to maintain a more upright position with less knee and hip flexion compared to the RLL and increased ankle flexion. This is consistent with research (7, 8, 38) that demonstrates a knee dominant strategy for moving load overhead from a front squat position.

Winwood et al. (39) found significant difference ($p < 0.005$) between their investigation of

SMLCJ compared to WCJ at the knee and hip whereas the current study demonstrated a correlation ($p < 0.01$) between BBPP and SMLP ($r = 0.658$) at knee angle during TS and BDD ($r = 0.827$). The significant kinematic differences in Winwood et al. (39) study can be attributed to the use of heavier loads than the current study. Subjects were tested at 70%1RM of their 1RM WCJ (116.7±20.4kg) that is 81.2 ± 20.4kg, compared to 52kg during the current study. This higher mass held out in front of the body for the SMLCJ further exaggerates the awkward position and the need hold a very upright torso where subjects needed to maintain a higher trunk and hip angle. It is likely that the use of less mass (52kg) in the current was more controllable and less unwieldy during the SMLP than the load used in Windwood et al. (39) group. Thereby allowing subjects to regulate positions and have more transfer and a high correlation between BBPP and SMLP.

As the subject moves through the assent phase of the lifts from BDD to LC the RLL demonstrates higher hip (98.7°) knee (89.1°) and ankle (24.7°) extension compared to BBPP at hip (21.1°), knee (45°) and ankle (24.3°). SMLP demonstrated the lowest levels of extension at hip (15.9°), knee (40.7°) and ankle (18.4°). These findings are consistent with research (7) that demonstrated moving a load from an anterior position to overhead requires increased levels of knee flexion whereas unloaded vertical jumping and landing involved a more balanced knee and hip strategy because subjects start from a more flexed position. From the results in the current study the RLL demonstrates similar kinematic traits as the jump in the Cleather et al. (7) study. It involves lower limb flexion and extension than BBPP and SMLP and less of a knee dominant movement strategy. In contrast, the SMLP demonstrates a knee dominant strategy with very little hip flexion and extension. Although the positioning of the strongman log across the clavicles and anterior deltoids is closer to the subjects' center of mass than the RLL, the large diameter of the load increases movement control requirements.

To maintain the strongman log position subjects must maintain an extended hip, any flexion of the hip during the countermovement could cause the subject to lose to log forward. This requires that more movement is generated from the knee and ankle for SMLP than the RLL. The knee position of the SMLP shares a very high, almost perfect correlation with the BBPP ($r = 0.827$). This correlation highlights the knee dominant strategy of these lifting conditions, whereas the RLL movement features increased movement at the hip. The unloaded vertical movement of subjects during the countermovement of the RLL features more movement at the hip. Therefore, it is possible that the RLL has more mechanical similarity with a countermovement jump than either the BBPP or, SMLP (7, 8). However, it is noted that where the countermovement jump moves on a vertical trajectory, the RLL requires subjects to move both vertically and horizontally to lift the load which may impact mechanical similarity.

Although during the BBPP the barbell can rest in a more secure position across subjects' clavicles it also demonstrates a lower range of RoM at the hip than the RLL, the RoM is more than that demonstrated for the SMLP but not significantly. To perform the BBPP and SMLP instructions to subjects were to move the load overhead as fast as possible. This left interpretation open to the subject. If direct instructions were given to focus on the performance of the countermovement the BBPP may have demonstrated more movement at the hip (38). Whereas the SMLP is unlikely to change even given different constraints as the diameter of the load necessitates an extended hip to maintain an upright torso and not lose the bar forward (38). The kinematics and movement strategies to maintain position and control the load lifted affect the kinetics of each group differently.

Subjects performing the BBPP demonstrate highest peak force (PF) 209.5 ± 35.2, it can be speculated that this is because of the control over the barbell and the vertical trajectory of the load. There was a very high correlation between SMLP and BBPP PF ($r = 0.928$, $p \leq 0.01$). When performing the SMLP the large diameter of the log and anterior resting position across the clavicles may require movement of the load in a more controlled manner than the BBPP which, when pressed, can pass the face much closer (31, 39). This is further demonstrated by the SMLP requiring most time to PF (0.66 ± 0.88s) and was significantly slower to PF than the RLL (0.49 ± 1.86s). The speed of movement can be attributed to maintaining position with the load. The BBPP demonstrates a non-significantly faster time than SMLP to PF and the RLL is fastest overall to PF. As the lifter has no load for the countermovement portion of the RLL and accepts the load of the jumper while moving out of the BDD position it allows for a faster decent than BBPP and SMLP. Furthermore, at the terminal phase of the RLL the subject has less load to decelerate, that is during the BBPP and SMLP subjects must decelerate the load such that they can control positioning. During the RLL subjects are accepting the jumper's load following their countermovement, along with the AAAL lifting from the anterior position of the jumper. This would reduce requirement to decelerate the jumpers load during the RLL and aid to reduce time to PF. The control strategy of increased hip and knee flexion and extension and may also attribute to the faster RLL time to PF.

However, the RLL time to PF also had the highest standard deviation amongst lifting conditions. Subject variability was highest within the RLL condition (0.49 ± 1.86s) compared to BBPP (0.62 ± 1.05) and SMLP (0.66 ± 0.88s). This demonstrates that although the RLL group mean was fastest across lifting conditions, intra-group control strategies varied in respect to time. This is likely due to variables outside of the subject's control. During the RLL the TS must account for the jumpers' varied motion between attempts and the AAAL lifting from the anterior side who also makes nuanced adjustments between attempts.

Therefore, a high degree of variability exists that is not present during BBPP and SMLP where the TS has control of the load throughout the entirety of the attempt.

Whilst demonstrating fastest time to PF the RLL demonstrates the lowest PF, significantly lower than BBPP. Although subjects were unloaded during the countermovement of RLL allowing for faster transition, the assent from BBD to LC generated the lowest PF. It can be speculated that the lower PF is a result of the unloaded countermovement. It is also possible that movement control strategies limit PF while TS anticipates the potentially chaotic movement of the RLL jumping subject during the countermovement and then accepts the load as the jumper moves vertically. During the RLL the jumper is further anteriorly situated than the load in either the BBPP and SMLP and whilst the barbell and strongman log were pressed overhead in a vertical trajectory the RLL jumper is pushed up and forward. Adjustments must be made by the TS over a very short time course (0.49 ± 1.86s) which may also contribute to a reduction in PF.

The BBPP demonstrated the lowest impulse across lifting conditions of 56.56 N-s in accordance with the fastest time to PF (0.27s) and highest PF (209.5N) as the uniformed weight and position of barbell allows for an effective control strategy. The impulse for RLL was 75.55 N-s, as time to PF (0.49s) was second to BBPP, however it did demonstrate the lowest PF (154.2N). The SMLP exhibits the longest impulse of 128.5 N-s, as the PF (194.7) was second to BBPP and time to PF was slowest of lifting conditions (0.66s). It can be inferred from these results that the unloaded countermovement of the RLL allows for a faster transition and lower impulse than SMLP even though the PF generated was lower than that of SMLP, albeit non-significantly. It can also be inferred from results that the SMLP required more control through the countermovement due to the load position and awkward nature of the load resulting in the longest impulse across lifting conditions. Therefore, the SMLP would not be an appropriate training exercise to develop qualities specifically for the RLL due to low correspondence of mechanical specificity.

A potential limitation to this study is the performance of lifts by subjects wearing training shoes upon the force plate. In game situations players wear specialized studded boots and perform the RLL on a turfed surface which may alter kinematics and kinetics, this should be considered for future research. Also, for logistical reasons the order of loading conditions was not randomized; subjects completed all 3 RLL attempts then, BBPP followed by SMLP this may have influenced subjects and caused a practice effect through testing. Future research may consider this and organize a randomized test order. Future research may also consider using logs of different diameters as this will alter positioning, thereby changing kinematics and kinetics and may be worthy of further study. Changing lifting constraints may also be considered in future research. The currently study used a barbell and strongman log load of 52kg. Manipulating the load may impact results by altering kinetics and kinematics seen across respective lifting conditions as seen in previous research (8, 39). Therefore, future research should consider the use of a range of different loads and investigate what impact this has on the biomechanics of the lifts.

PRACTICAL APPILICATIONS

The results of this study provide practitioners with the first biomechanical description of the RLL kinematic and kinetic characteristics. From a practical standpoint, the results suggest that BBPP and SMLP have a low correspondence with the RLL and are not appropriate as specific training exercises to enhance the RLL skill. Therefore, because of the differences in movement strategies the BBPP and SMLP should be used as general exercises to develop biomechanics appropriate to the RLL. Both BBPP and SMLP can be programed in off season mesocycles as general training exercises to develop different physical qualities such as lower impulse (BBPP). The SMLP can be used to lift under different constraints thereby emphasising different movement strategies such as a knee dominant control strategy. These general training exercises can contribute to the preparation of the athlete for their return into training for the competitive rugby season and specific practice for the RLL

REFERENCES

1. Arabatzi, F, and Kellis, E. Biomechanical analysis of the snatch movement and vertical jump: Similarities and differences. *Hellenic Journal of Physical Education & Sport Science* 29: 185-199, 2009.
2. Beardsley, C, and Contreras, B. The increasing role of the hip extensor musculature with heavier compound lower body movements and more explosive sport actions. *Strength and Conditioning Journal* 36: 49-55, 2014.
3. Bennett, S. Using strongman exercises in training. *Strength and Conditioning Journal* 30: 42-43, 2008.
4. Berning, JM, Adams, KJ, Climetein, M, and Stamford, BA. Metabolic demands of junkyard training: Pushing and pulling a motor vehicle. *Journal of Strength and Conditioning Research* 21: 853-856, 2007.
5. Bryanton, MA, Kennedy, MD, Carey, JP, and Chiu, LZ. Effect of squat depth and barbell load on relative muscular effort in squatting. *Journal of Strength and Conditioning Research* 26: 2820–2828, 2012.
6. Chiu, LZF, and Schilling, BK. A primer on weightlifting: From sport to sports training. *Strength and Conditioning Journal* 27: 42-48, 2005.
7. Cleather, DJ, Goodwin, JE, and Bull, AM. Intersegmental moment analysis characterizes the partial correspondence of jumping and jerking. *Journal of Strength and Conditioning Research* 27: 89–100, 2013.
8. Cushion, EJ., Goodwin, JE, and Cleather, DJ. Relative intensity influences the degree of correspondence of jump squats and push jerks to countermovement jumps. *Journal of Strength and Conditioning Research* 30: 1255-1264, 2015.

9. Flanagan, SP and Salem, GJ. Lower extremity joint kinetic responses to external resistance variations. *J Appl Biomech* 24: 58–68, 2008.

10. Garhammer, J. Power production by Olympic weightlifters. *Medicine and Science in Sports and Exercise* 12: 54–60, 1980.

11. Garhammer, J, and Gregor, R. Propulsion forces as a function of intensity for weightlifting and vertical jumping. *J. Appl. Sports Sci. Res* 6: 129–134, 1992.

12. Ghigiarelli, JJ, Sell, KM, Raddock, JM, and Taveras, K. Effects of strongman training on salivary testosterone levels in a sample of trained men. *Journal of Strength and Conditioning Research* 27: 738-747, 2013.

13. Glaister, M, Witmer, C, Clarke, DW, Guers, JJ, Heller, JL, and Moir, G. Familiarization, reliability and evaluation of a multiple sprint running test using self-selected recovery periods. *J Strength Cond Res* 24: 3296–3301, 2010.

14. Harris, NK, Woulfe, CJ, Wood, MR, Dulson, DK, Gluchowski, AK, and Keogh, JB. Acute physiological responses to strongman training compared to traditional strength training. *Journal of Strength and Conditioning Research* 30: 1397-1408, 2015.

15. Holmberg, PM. Weightlifting to improve volleyball performance. *Strength and Conditioning Journal* 35: 79-88, 2013.

16. Jones, R. Rugby world cup statistical report. International Rugby Board. Retrieved from www.worldrugby.org/game-analysis. 2015.

17. Keogh, JWL, Payne, AL, Anderson, BB, & Atkins, PJ. A brief description of the biomechanics and physiology of a strongman event: The tire flip. *Journal of Strength and Conditioning Research* 24: 1223-1228, 2010.

18. Keogh, JWL, Kattan, A, Logan, S, Bensley, J, Muller, C, and Powell, L. A preliminary kinematic gait analysis of a strongman event: The farmers walk. *Sports* 2: 24-33, 2014.

19. Lake, J, Lauder, M, Smith, N, and Shorter, K.A. Comparison of ballistic and non-ballistic

lower-body resistance exercise and the methods used to identify their positive lifting phases. *J Appl Biomech* 28: 431–437, 2012.

20. Lake, JP, Mundy, PD, and Comfort, P. Power and impulse applied during push press exercise. *Journal of Strength and Conditioning Research*, 28: 2552-2559, 2014.
21. Lees A, Vanrenterghem J, and De Clercq D. The maximal and submaximal vertical jump: Implications for strength and conditioning. *Journal of Strength and Conditioning Research* 18: 787–791, 2004.
22. Loturco, I, Kobal, R, Maldonado, T, Piazzi, AF, Bottino, A, Kitamura, K, Abad, CCC, Pereira, LA, and Nakamura, FY. Jump squat is more related to sprinting and jumping abilities than Olympic push press. *International Journal of Sports Medicine* Epub ahead of print, 2015.
23. Loturco, I, Pereira, LA, Kobal, R, Maldonado, T, Piazzi, AF, Bottino, A, Kitamura, K, Abad, CCC, de Arruda, M, and Nakamura, FY. Improving sprint performance in soccer: Effectiveness of jump squat and Olympic push press exercises. *PLOS One* 1-12, 2016.
24. McGill, SM, McDermott, A, and Fenwick, CMJ. Comparison of different strongman events: Trunk muscle activation and lumbar spine motion, load, and stiffness. *Journal of Strength and Conditioning Research* 23: 1148-1161, 2009.
25. Riemann, B, Congleton, A, Ward, R, and Davies, GJ. Biomechanical comparison of forward and lateral lunges at varying step lengths. *J Sports Med Phys Fitness* 53: 130–138, 2013.
26. Sayers, M. A three-dimensional analysis of lineout throwing in rugby union. *Journal of Sports Sciences* 22: 498-499, 2004.
27. Sayers, MGL. Kinematic analysis of line-out throwing in elite international rugby union. *Journal of Sports Science and Medicine* 10: 553-558, 2011.
28. Schache, AG, Blanch, PD, Dorn, TW, Brown, NA, Rosemond, D, and Pandy, MG. Effect

of running speed on lower limb joint kinetics. *Medicine & Science in Sports & Exercise* 43: 1260-1271, 2011.

29. Stone, MH, Pierce, KC, Sands, WA, and Stone, ME. Weightlifting: A brief overview. *Strength and Conditioning Journal* 28: 50-66, 2006.
30. Trewartha, G, Casanova, R, and Wilson, C. A kinematic analysis of rugby lineout throwing. *Journal of Sports Sciences* 26: 845-854, 2008.
31. Vanezis, A, and Lees, A. A biomechanical analysis of good and poor performers of the vertical jump. *Ergonomics* 48: 1594–1603, 2005.
32. Waller M, Piper T, and Townsend R. Strongman Events and Strength and Conditioning Programs. *Strength and Conditioning Journal* 25: 44-52, 2003.
33. Winchester, JB, Erickson, TM, Blaak, JB, and McBride, JM. Changes in bar path kinematics and kinetics after power clean training. *Journal of Strength and Conditioning Research* 19: 177-183, 2005.
34. Winwood, PW, Keogh, JWL, and Harris, NK. The strength and conditioning practices of strongman competitors. *Journal of Strength and Conditioning Research* 25: 3118-3128, 2011
35. Winwood, PW, Keogh, JWL, and Harris, NK. Interrelationships between strength, anthropometrics, and strongman performance in novice strongman athletes. *Journal of Strength and Conditioning Research* 26: 513-522, 2012.
36. Winwood, PW, Cronin, JB, Brown, SR, and Keogh, JWL. A biomechanical analysis of the farmers walk, and comparison with the deadlift and unloaded walk. *International Journal of Sports Science & Coaching* 9: 1127-1143, 2014.
37. Winwood, PW, Cronin, JB., Keogh, JWL, Dudson, MK, and Gill, ND. How coaches use strongman implements in strength and conditioning practice. *International Journal of Sports Science & Conditioning* 9: 1107-1125, 2014.

38. Winwood, PW, Hume, PA, Cronin, JB, and Keogh, JWL. Retrospective injury epidemiology of strongman athletes. *Journal of Strength and Conditioning Research* 28: 28-42, 2014.

39. Winwood, PW, Cronin, JB, Brown, SR, and Keogh, JWL. A biomechanical analysis of the strongman log lift and comparison with weightlifting's clean and jerk. *International Journal of Sports Science & Coaching* 10: 869-886, 2015.

40. Winwood, PW, Cronin, JB, Brown, SR, and Keogh, JWL. A biomechanical analysis of the heavy sprint style sled pull and comparison with the back squat. *International Journal of Sports Science & Coaching* 10: 851-868, 2015.

41. Winwood, PW, Cronin, JB, Postthumus, LR, Finlayson, SJ, Gill, ND, and Keogh, JWL. Strongman vs traditional resistance training effects on muscular function and performance. *Journal of Strength and Conditioning Research* 29: 429 – 439, 2015.

42. Woulfe, C, Harris, N, Keogh, JW, and Wood, M. The physiology of strongman training. *Strength and Conditioning Journal* 36: 84 – 94, 2014.

43. Wu, G, Siegler, S, Allard, P, Kirtley, C, Leardini, A, Rosenbaum, D, Whittle, MD, Lima, D, Cristofolini, L, Witte, H, Schmid, O, and Stokes, I. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion— Part I: Ankle, hip, spine. *Journal of Biomechanics* 35: 543–548, 2001.

44. Wu, G, van der Helm, FC, Veeger, H, Makhsous, M, Van Roy, P, Anglin, C, Nagels, J, Karduna, A, McQuade, K, Wang, X, Werner, F, and Buchholz, B. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: Shoulder, elbow, wrist and hand. *Journal of Biomechanics* 38: 981–982, 2005.

45. Zemke, B, and Wright, G. The use of strongman type implements and training to increase sport performance in collegiate athletes. *Strength and Conditioning Journal* 33: 1-7, 2011.

APPENDIX

Ethics application

St Mary's University Twickenham London

St Mary's Ethics Application Checklist

The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application.

Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be re-submitted at a later date.

	Enclosed? (delete as appropriate)		Version No
Document	Yes	Not applicable	
1. Application Form	Mandatory		
2. Risk Assessment Form	✓		
3. Participant Invitation Letter			
4. Participant Information Sheet	Mandatory		
5. Participant Consent Form	Mandatory		
6. Parental Consent Form		✓	
7. Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails		✓	
8. Letter from host organisation (granting permission to conduct the study on the premises)		✓	
9. Research instrument, e.g. validated questionnaire, survey, interview schedule		✓	
10. DBS (to be sent separately)		✓	

11. Other Research Ethics Committee application (e.g. NHS REC form)		✓	
12. Certificates of training (required if storing human tissue)		✓	

I can confirm that all relevant documents are included in order of the list and in one PDF document (any DBS check to be sent separately) named in the following format: *Full Name, School, Supervisor.*

Signature of Applicant:

Signature of Supervisor:

St Mary's University Twickenham London

Ethics Application Form

1) Name of proposer(s)	Oliver William Driver
2) St Mary's email address	145370@live.stmarys.ac.uk
3) Name of supervisor	Phil Price

4) Title of project The biomechanical similarity between barbell push jerks, strongman log jerks and the rugby lineout lift

5) School or service	St Marys University
6) Programme (whether undergraduate, postgraduate taught or postgraduate research)	Strength and Conditioning
7) Type of activity/research (staff/undergraduate student/postgraduate student)	MSc Postgraduate research

8) Confidentiality

Will all information remain confidential in line with the Data Protection Act 1998?	YES

9) Consent	
Will written informed consent be obtained from all participants/participants' representatives?	YES

10) Pre-approved protocol	
Has the protocol been approved by the Ethics Sub-Committee under a generic application?	NO

11) Approval from another Ethics Committee	
a) Will the research require approval by an ethics committee external to St Mary's University?	NO
b) Are you working with persons under 18 years of age or vulnerable adults?	NO

12) Identifiable risks	
a) Is there significant potential for physical or psychological discomfort, harm, stress or burden to participants?	NO
b) Are participants over 65 years of age?	NO
c) Do participants have limited ability to give	NO

voluntary consent? This could include cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment.	
d) Are any invasive techniques involved? And/or the collection of body fluids or tissue?	NO
e) Is an extensive degree of exercise or physical exertion involved?	NO
f) Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	NO
g) Are drugs or other substances (including liquid and food additives) to be administered?	NO
h) Will deception of participants be used in a way which might cause distress, or might reasonably affect their willingness to participate in the research? For example, misleading participants on the purpose of the research, by giving them false information.	NO
i) Will highly personal, intimate or other private and confidential information be sought? For example sexual preferences.	NO
j) Will payment be made to participants? This can include costs for expenses or time.	NO
k) Could the relationship between the researcher/ supervisor and the participant be such that a participant might feel pressurised to take part?	NO
l) Are you working under the remit of the Human Tissue Act 2004?	NO

13)Proposed start and completion date
Please indicate: • When the study is due to commence. • Timetable for data collection. • The expected date of completion. Please ensure that your start date is at least 3 weeks after the submission deadline for the Ethics Sub-Committee meeting.
The study will commence once ethics has been approved. The data will be collected over 6 days with the expected date of completion by 21st March 2016

14)Sponsors/Collaborators
Please give names and details of sponsors or collaborators on the project. This does not include your supervisor(s) or St Mary's University. • Sponsor: An individual or organisation who provides financial resources or some other support for a project. • Collaborator: An individual or organisation who works on the project as a recognised contributor by providing advice, data or another form of support.
N/A

15. Other Research Ethics Committee Approval
• Please indicate whether additional approval is required or has already been obtained (e.g. the NHS Research Ethics Committee).

- Please also note which code of practice / professional body you have consulted for your project.
- Whether approval has previously been given for any element of this research by the University Ethics Sub-Committee.

N/A

16. Purpose of the study

In lay language, please provide a brief introduction to the background and rationale for your study.

- Be clear about the concepts / factors / performances you will measure / assess/ observe and (if applicable), the context within which this will be done.
- Please state if there are likely to be any direct benefits, e.g. to participants, other groups or organisations.

The rugby lineout (RL) if of considerable importance during rugby matches (Jones, 2015). Successful completion of RL allows teams to maintain or, steal posesition of the ball and increases scoring opportunities. At present, investigations into the RL are focussed solely upon throwing (Sayers, 2004, 2011; Trewartha, Casanova, & Wilson, 2008), no literature exists on the RL lift. This work will specifically address the kinematics and kinetics of RL lift, that is, the biomechanics of the RL jumper during a simulated RL lift. During training the most effective exercises are selcted to improve sporting activities, in this case the rugby lineout lift (RL). As no research currently exists for the most effective exercise choice, coaches must select what they feel is the most appropriate movements to use from existing, general and unrelated information. Therefore this investigation will also analyze two training movements that maybe appropriate exercises for use to increase the effectiveness and success of the RL lift. These exercises are the barbell push jerk (BBPJ) and strongman log jerk (SMLJ). They are selected as they may produce similar joint excursions of the lower limbs during execution of the RL lift.
The results of the BBPJ and SMLJ will be compared to each other and the RL lift to determine which lift is most appropirate to use in training.
Data gathered as a result of this investigation will form part of the literature on the RL clarifying the biomechanics of the lower limb during the RL along with the lower limb joint execusions of two commonly used exercises. This information may help inform coaching practices and add to literature, furthering the knowledge base of the RL and biomechanics of commonly used training exercises.

17. Study Design/Methodology

In lay language, please provide details of:

a) The design of the study (qualitative/quantitative questionnaires etc.)
b) The proposed methods of data collection (what you will do, how you will do this and the nature of tests).
c) You should also include details regarding the requirement of the participant i.e. the extent of their commitment and the length of time they will be required to attend testing.
d) Please include details of where the testing will take place.
e) Please state whether the materials/procedures you are using are original, or the intellectual property of a third party. If the materials/procedures are original, please describe any pre-testing you have done or will do to ensure that they are effective.

Testing will be undertaken at Code Fitness gymnasium in Newark upon Trent, Nottinghamshire. The equipment used for testing and set up of instrumentation will be similar to previous research (Cushion et al. 2016). A portable force plate (Pasport Force Platform PS-2141, 370 mm x 370 mm; Pasco, Roseville, CA, USA) arranged within a surrounding platform structure. Kinetic data will be recorded by a video camera (Sony HDR-FX1000E, Sony, Surrey, UK) sampling at 200Hz, it will be positioned so as to capture movement in the sagital plane. Digitized coordinate data will be filtered using a fourth-order dual-pass Butterworth filter with a cutoff frequency of 6 Hz in MATLAB (MatLab; The Mathworks, Inc., Natick, MA, USA). Markers will be placed on bony landmarks of anatomical structures on the shoulder (acromioclavicular joint), hip (greater trochanter), knee (lateral ridge of tibial plateau), ankle (apex of the lateral malleolus), and distal end of the foot (metatarsus head). Subjects will be asked to wear comfortable training clothing. They will be permitted to continue regular training activities outside of the testing but asked to refrain from caffeine or any intense exercise 24 hours prior to test day.
An olympic weightlifting barbell (Again Faster, Nottingham, UK) will be used for BBPJ along with weightlifting bumper plates (Exertrain, Savage Strength, Wiltshire, UK). A metal strongman log will be used for the SMLJ weighing 33kg (Savage Strength, Wiltshire, UK). Participants will be required to attend a one testing session for the the barbell push jerk, strongman log jerk and RL lift. During testing the participants will follow a standardized warm up protocol. This will consist of a circuit of 10 bodyweight squats, 10 press-ups and 10 lunges completed 3 times. The warm up will be presented on an information sheet prior to participation and will also be verbally described and demonstrated by the principle researcher before participants comence. Participants will then warm up with an unloaded barbell completing 10 push presses and 10 back squats. Following this they will instructed to perform single repetions of the RL lift on the selected participant. Instructions are presented by way of written and verbal directions along with diagrams on the information sheet, it is however, a movement participants are competent at performing as part of the game of rugby. The participants will be positioned as in a RL lift. That is, a jumper as close to the average anthropometrics reported by Jones (2015) as possible and another participant positioned anteirorly. These participants will also remain the same for the entire test. Another partcipant will be positioned posteriorly, to the rear.of the jumper The participant positioned posteriorly will have the reflective markers attached to their bony landmarks will have three attempts of the RL lift. They will

then will be replaced by another participant until all participants have been involved in the movement.
The camera will be positioned to recored kinematic data in the sagital plane. The participant to the rear will also be positioned upon the force plate to collect kinetic data. Following performnce of the RL lift all participants are required to then perform a BBPJ and a SMLJ in a randomised order. As with the RL lift instructions are presented by way of written and verbal directions and diagrams on the information sheet. The weight of both BBPJ and SMLJ will be constant at 55kg as that is half of the average weight of a forward player (Jones, 2015) and will simulate the proportion of weight a forward player lifts during the RL lift. Participants will have 3 attempts with each of the appuratus whilst positioned on the force plate being filmed in the sagital plain wearing the refective markers
10 – 15 participants will take part to provide appropriate statistical power. The use of a repeated measures analysis of variance (ANOVA) statistical test will be performed. After assessing linearity of data, a Pearson's correlation coefficient will be used to determine the relationship between joint moment and joint impulse across different joints between the RL lift, BBPJ and SMLJ data. For analysis of the kinetic data, a repeated measures of ANOVA will be used for the joint X load interaction for each lift. Bonferroni adjusted t-test will be used for post hoc testing if ANVOA produces significant results. Significance levels will be set at $p<0.05$ for all data. Data will be analyzed using Windows Microsoft Excel 2007 (Microsoft Corp, Redmond, WA, USA) and IBM SPSS Statistics (Version 21; IBM Corp, Armonk, NY, USA).

18. Participants

Please mention:

a) The number of participants you are recruiting and why. For example, because of their specific age or sex.
b) How they will be recruited and chosen.
c) The inclusion/exclusion criteria.
d) For internet studies please clarify how you will verify the age of the participants.
e) If the research is taking place in a school or organisation then please include their written agreement for the research to be undertaken.

10 - 15 male semi-professional rugby players from Newark RFC. They have been selected as they are familiar with RL lifts, training apparatus and movements. Members of the team have a individual broad and varied playing history, however, the universal factor is an enduring commitment of playing at various higher levels of competition. Preference will be given to participants who play in a forward position and have anthropometics similar

to the averages identified by Jones (2015). They are a cohort local to the testing location with avilability. Advertising sheets were distributed at the club site. All responders were considered but, preference was given to those that play in the forward positions as they are the individuals that perform the RL lift in game conditions.

19. Consent

If you have any exclusion criteria, please ensure that your Consent Form and Participant Information Sheet clearly makes participants aware that their data may or may not be used.

a) Are there any incentives/pressures which may make it difficult for participants to refuse to take part? If so, explain and clarify why this needs to be done

b) Will any of the participants be from any of the following groups?

- Children under 18
- Participants with learning disabilities
- Participants suffering from dementia
- Other vulnerable groups.

c) If any of the above apply, does the researcher/investigator hold a current DBS certificate? A copy of the DBS must be supplied separately from the application.

d) How will consent be obtained? This includes consent from all necessary persons i.e. participants and parents.

a) No
b) No
c) No
d) Participants will be given an information sheet and provide written consent form

20. Risks and benefits of research/ activity

a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle) associated with this study? If so please provide details, including information on how these will be minimised.

b) Please explain where the risks / effects may arise from (and why), so that it is clear why the risks / effects will be difficult to completely eliminate or minimise.

c) Does the study involve any invasive procedures? If so, please confirm that the researchers or collaborators have appropriate training and are competent to deliver these procedures. Please note that invasive procedures also include the use of deceptive procedures in order to obtain information.

d) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting? If so, please clarify why this information is necessary (and if applicable, any prior use of the questionnaire/interview).

e) Please describe how you would deal with any adverse reactions participants might experience. Discuss any adverse reaction that might occur and the actions that will be taken in response by you, your supervisor or some third party (explain why a third party is being used for this purpose).

f) Are there any benefits to the participant or for the organisation taking part in the research (e.g. gain knowledge of their fitness)?

---

a) Participants will experience a small degree of physical stress during the study. This level of physical discomfort is transient (i.e. recoverable)..
b) A low level of risk exists as participants as they will lift loaded implements above their head. The risk will be reduced by carrying out a risk assessment and by using the warm up protocol described in Section 17. Participants are familiar with testing movements from their previous training. Testing sessions will be supervised by an experienced exercise physiologist.
c) No
d) No
e) No adverse reactions are expected as procedures have low risk; however, if they do occur, a trained first aider will be contacted and incident will be reported immediately.
f) The participants will be provided with a brief verbal explanation of their test results along with a report on the overall results from the study.

21. Confidentiality, privacy and data protection

a) What steps will be taken to ensure participants' confidentiality?

- Please describe how data, particularly personal information, will be stored (all electronic data must be stored on St Mary's University servers).
- Consider how you will identify participants who request their data be withdrawn, such that you can still maintain the confidentiality of theirs and others' data.

b) *Describe how you will manage data using a data a management plan.*

- *You should show how you plan to store the data securely and select the data that will be made publically available once the project has ended.*
- *You should also show how you will take account of the relevant legislation including that relating data protection, freedom of information and intellectual property.*

c) Who will have access to the data? Please identify all persons who will have access to the data (normally yourself and your supervisor).

d) Will the data results include information which may identify people or places?

- Explain what information will be identifiable.
- Whether the persons or places (e.g. organisations) are aware of this.
- Consent forms should state what information will be identifiable and any likely outputs which will use the information e.g. dissertations, theses and any future publications/presentations.

a) All participant information will be safeguarded and remain confidential during and after the research project in line with the data protection act 1998. All data will be collected and stored electronically on St Mary's University servers. All paper data will be locked in a cabinet in a locked office accessed only by the research group. All participants will have a code attached to their name only know to the research group, which can be used to identify data if it needs to be withdrawn. All data will be disposed securely after 5 years. Anyone who withdraws from the research project will have all information and data collected destroyed.
b) All participants will have a number code attached to their name and this code will be how data will be selected and made public when the research project is finished. All data will be collected and stored on a password-protected computer known only by the research group on St Marys University servers. Data will be presented as group averages thus no allowing identification of individuals.
c) Mr Oliver Driver, Mr Phil Price and Ms Emily Cushion
d) No

22. Feedback to participants
Please give details of how feedback will be given to participants: • As a minimum, it would normally be expected for feedback to be offered to participants in an acceptable to format, e.g. a summary of findings appropriately written. • Please state whether you intend to provide feedback to any other individual(s) or organisation(s) and what form this would take.
Feedback from this study will only be given in a summary of findings. Any individual data that can be provided on request will only relate to post testing and will be provided in a comprehensive text.

The proposer recognises their responsibility in carrying out the project in accordance with the University's Ethical Guidelines and will ensure that any person(s) assisting in the research/ teaching are also bound by these. The Ethics Sub-Committee must be notified of, and approve, any deviation from the information provided on this form.

Signature of Proposer(s)	Date: 17/12/2016
Signature of Supervisor (for student research projects)	Date:

Approval Sheet

Name of applicant: Oliver Driver Name of supervisor: Phil Price & Emily Cushion Programme of study: Strength and Conditioning MSc Title of project: The biomechanical similarity between barbell push jerks, strongman log jerks and the rugby lineout lift

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1 Approved at Level 1 Signature of supervisor (for student applications)... Date..
SECTION 2 Refer to School Ethics Representative for consideration at Level 2 or Level 3 Signature of supervisor... Date...
SECTION 3 To be completed by School Ethics Representative Approved at Level 2 Signature of School Ethics Representative..

Date..
SECTION 4 To be completed by School Ethics Representative. Level 3 consideration required byt the Ethics Sub-Committee (including all staff research involving human participants) Signature of School Ethics Representative.. Date.. Level 3 approval – confirmation will be via correspondence from the Ethics Sub-Committee

St Mary's University Twickenham London

Participant Information sheet

The biomechanical similarity between barbell push jerks, strongman log jerks and the rugby lineout lift

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Take time to read the following information carefully and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information. Thank you for reading this:

What is the purpose and aim of our research?
The lineout in rugby is one of the most important aspects of the game. However, there is a gap in existing literature about the biomechanics of the rugby lineout jump The aim of the study is to identify the kinetics and kinematics of the rugby lineout and compare the data to two commonly used training resistance exercises

Why have I been invited?
You have been chosen because you are healthy male, who regularly plays rugby and is over the age of 18 and under the age of 45.

Who is organising the research?
The research is being organised by Oliver Driver, Phil Price (Lecturer in Strength and Conditioning and Biomechanics) and Emily Cushion.

What will happen to the results of the study?
The results will be given within a "summary of findings" document after the study is complete. You will only be given overall results and not the results of any other participant that took part. No further individuals or organisations will be given these findings.

Source of funding for the research
There are no external sources of funding for this study.

Contact for further information
Oliver Driver (145370@live.stmarys.ac.uk)

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form and PAR-Q. You will be given copies of these. You are still free to withdraw at any time with no questions asked and no penalty.

What will happen if you agree to take part?

You will be needed on a sinlge occasion at Code Fitness, Unit 2 Maltkin Lane, Newark. The visits will comprise. The session will take between 1.5-2 hours. During the task your weight will be taken and you will complete necessary questionnaires and consent forms. Any final questions that you might have in regards to the procedures can be asked here or throughout the rest of the study. During the three experimental trials, you will follow the procedure provided below.

Whether there are any special precautions you must take before, during or after taking part in the study
You will be asked to refrain from consuming caffeine and alcohol for 24 hours prior to each study. We will also ask you to avoid any strenuous exercise at all for 48 hours prior to the study.

On the day of the trial
The testing protocol will be the following:

You will arrive at Code Fitness, Unit 2 Maltkin Lane, Newark. Where upon you will be given a participat information sheet with exercise directions. An initial warm up will be verbally described and demonstrated by the principle investigator comprising of; 10 repetitions of squat, press ups and lunges repeated three times through. Following this three sets of 10 repetitions of the barbell back squat and barbell over head press will be repeated using a 20kg bar.

Following this a jumper and a front lifter will be selected. These participants will remain the same for the entire study. The rest of the participants will have reflective markers attached by tempory adhevise to their shoulder, hip, knee, ankle and foot.They will then be directed in to position on the force plate whilst being filmed and execute the posterior lift in a simulated rugby line out. Participants will have three attempts. When all participants have completed this section they will perform both a barbell push jerk and strongman log jerk in a randomised order. Both implements will weigh 55kg. Information sheets will be distributed with visual and written instructions, the principle investigator will verablly decribe and practically demonstrate what movements are required. Participants will then have three attempts at each movement.

Figure 1. The rugby lineout lift Figure 2. The barbell push jerk

Figure 3. The strongman log jerk – starting and finishing positions

Are there any risks or side effects?
Any scientific investigate involving human participants carries an element of risk.
These are movements that have been selected because they are common resistance training exercises and should be familiar to most participants. The use of jerk blocks will allow you to drop the bar/log if required. The weight is set at 55kg which is half of the average second row player and should not pose any strength issues.

Agreement to participate in this research should not compromise your legal rights if something goes wrong
Research can carry unforeseen risks and we want you to be informed of your rights in the unlikely event that any harm should occur as a result of taking part in this study. Every care will be taken to ensure that your well-being and safety are not compromised during the course of the study. St Marys University also has insurance arrangements in place in the unlikely event that something does go wrong and you are harmed as a result of taking part in the research study

What will happen to any information/data/samples that are collected from you?
Only the researchers will have access to the data collected during the study. However, your identity will not be revealed. All information which is collected about you during the course of the research will be kept strictly confidential. We will keep a record that you have taken part in the study but will not keep any other personal information about you. Professional standards of confidentiality will be adhered and the handling, processing, storage and destruction of data will be conducted in accordance with the Data Protection Act (1998).

Are there any benefits from taking part?
There are several benefits for participants to participate in the study. All the participants will gain useful information in terms of their kinetics and kinematics whislt performing the movements.

How much time will I need to give up to take part in the project?
The total time commitment will be 1-2 hours over 1 day at Code Fitness, Newark.

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

Consent form

St Mary's University Twickenham London

NAME OF PARTICIPANT: ___________________________________

Title of the project: The biomechanical similarity between barbell push jerks, strongman log jerks and the rugby lineout lift

Principle investigator and contact details: Oliver Driver – 145370@live.stmarys.ac.uk

Members of the research team: Phil Price, Emily Cushion.

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)………………………….Signed………………..…..Date………………

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

I WISH TO WITHDRAW FROM THIS STUDY

Name: ___________________________________

Signed: _____________________________ Date: __________________

SCHOOL OF Sport, Health and Applied Science

CONFIDENTIAL Medical History / Physical Activity Readiness Questionnaire (PAR-Q) FORM

This screening form **must** be used in conjunction with an agreed Consent Form.

Full Name: ______ Date of Birth ______
Height (cm): ______ Weight (kg): ______

Have you ever suffered from any of the following medical conditions? If yes please give details:

	Yes	No	Details
Heart Disease or attack	☐	☐	______
High or low blood pressure	☐	☐	______
Stroke	☐	☐	______
Cancer	☐	☐	______
Diabetes	☐	☐	______
Asthma	☐	☐	______
High cholesterol	☐	☐	______
Epilepsy	☐	☐	______
Allergies	☐	☐	______
Other, please give details	☐	☐	______

Do you suffer from any blood borne diseases? If yes please give details;

Please give details of any **medication** you are currently taking or have taken regularly within the last year:

Please give details of any **musculoskeletal injuries** you have had in the **past 6 months** which have affected your capacity to exercise or caused you to take time off work or seek medical advice:

Other Important Information

If you **smoke** please indicate how many per day:

If you drink **alcohol** please indicate how many units per week:

Are you currently taking any **supplements or medication?** Please give details:

Is there any other reason that is not prompted by the above that would prevent you from participating within the relevant activity?

Signature (Participant): Date:

Signature (Test Coordinator*): Date:

*Test coordinator: The individual responsible for administering the test(s)/session and subsequent data collection